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(71)(72) Applicant and Inventor: STOBBE, Per [DK/DK]; Hjortekærsvej 176, DK-2800 Lyngby (DK).

(72) Inventor; and
(75) Inventor/Applicant *(for US only)* : HØJ, Jakob, Weiland [DK/DK]; Gentoftegade 58, DK-2820 Gentofte (DK).

(74) Agent: PLOUGMANN & VINGTOFT A/S; Sankt Annæ Plads 11, DK-1021 Copenhagen K (DK).

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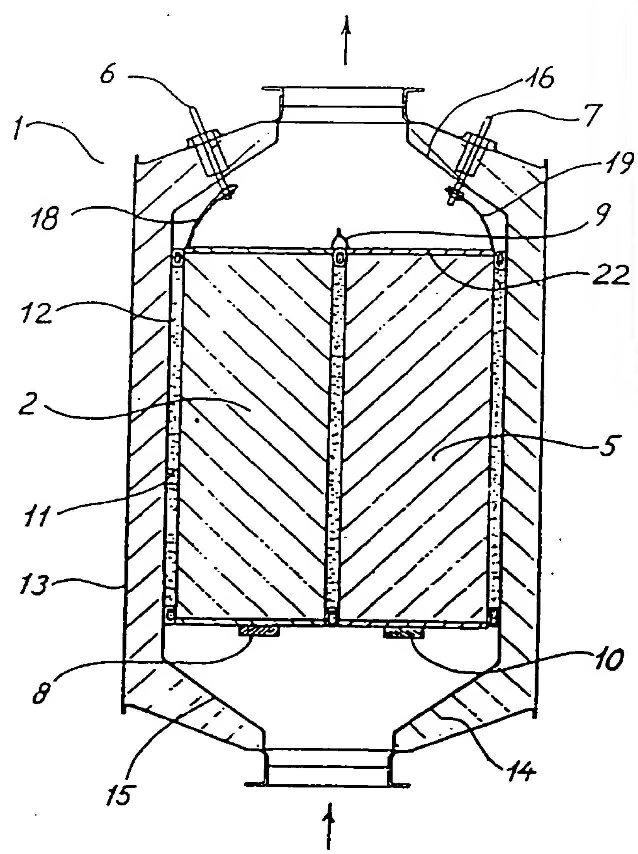
(57) Abstract

A filter unit for filtering exhaust gas from diesel engines comprises a casing and a filter body arranged in the casing. The filter body is composed of a plurality of filter segments extending in the axial direction of the casing, the filter segments being of a porous electrically conductive and heat-resistant material, such as silicon carbide (SiC), and being arranged adjacent to each other, but electrically insulated from each other at adjacent axially extending interfaces. Each segment in the filter unit is supplied with an electrode of an electrically conductive material at each end of the segment in axial direction. The resistance of each individual segment, measured from one electrode to the other, is in the range from 10 milliOhms to 100 Ohms. In the filter unit the segments may be electrically coupled in series by means of the electrodes. The electrodes may, alternatively, be connected t an electrical circuit permitting electrical connection of 2 or more segments variable between serial and parallel and combinations thereof. The cross section of each segment may be shaped as a circle sector, the segments together cross-sectionally constituting a circle. Due to the segmented design, the resistance of the unit can be adapted to the requirements of accumulators in vehicles.



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A filter unit and a filter body for filtering exhaust gas from diesel engines.

Strobbe

EP 0336 883 discloses filter units for this purpose made of a porous electrically conductive material, in particular SiC bodies made from silicon carbide (SiC) powder by extrusion with a binder and subsequent sintering. The typical filter design is a so-called "wall flow filter" of honeycomb structure.

Typically, the known filter bodies of this kind are manufactured in one piece, such as of a circular-cylindrical shape and are "canned" in suitable tubular casings with heat insulation around the filter bodies, the casing being adapted to be connected to an exhaust outlet from the diesel engine. In use, the filter accumulates soot particles from the diesel exhaust. At suitable intervals, e.g. once daily, the filter is cleaned by heating and incineration of the soot particles. In the filter units contemplated herein, the heating is performed by transmitting a current through the electrically conductive filter body, thereby heating the filter body due to the electrical resistance of the filter body.

JP3-121213 published May 23, 1991, discloses filter units of the above-mentioned type where the filter unit is divided into a number of sections in the axial direction of the casing. The individual sections are combined by means of a conductive material to form e.g. a circular cylindrical filter body, in order to compensate for thermal stresses.

The present invention deals with problems associated with the practical use of filter bodies of electrically conductive heat-resistant materials which are to be regenerated by heating by transmitting an electrical current through the filter. As mentioned above, such filters typically being made from metal or SiC or other electrically conductive heat-resistant ceramic type materials.

In these types of materials, it is desirable that the electrical resistance of the porous material as such is low, because otherwise, regeneration by electrical heating may not be possible. On the other hand, regeneration of such a filter, e.g. a SiC filter, will require large power supplies when the electrical resistance is low. Thus, using a 240 V power supply on a filter of SiC having dimensions suitable for e.g. a bus, a current of 1000 A will be transmitted through the filter. In this way, the filter would theoretically be regenerated in less than a second, but in practice, the filter will be totally destroyed. Therefore, a larger electrical resistance of the filter is required.

Using a 12 V or a 24 V power supply, as is the case in the accumulator of cars, fork lifts, trucks and so on, on a filter having dimensions suitable for cars, trucks and so on, the current required will be in the order of 100 A. A current of 50 A from an accumulator in a normal car can only be delivered for a few minutes, whereas a current of 100 A can be drawn from a bus in the order of 30 minutes and only once per hour. Regeneration of the filter will typically take about 20 minutes. However, a known SiC filter having dimensions suitable for a bus (e.g. a volume of 20-30 l, length 40 cm and diameter 30-50 cm) will not be regenerated by heating the filter with 24 V and 100 A (2,4 kW). In the order of 6 kW is required. Thus, regeneration of a typical SiC filter may not be performed using the known SiC filters due to the electrical characteristics of the setup.

According to the present invention, the filter body is split up into a number of filter elements which are electrically insulated from each other, but which together form a filter body having suitable dimensions from the point of view of filtering capacity, such as in filters of the type known <u>per se</u>. Splitting up the filter offers the possibility of connecting the individual filter elements so as to

obtain a wider range of possible electrical resistances of the filter without sacrificing filtering capability.

In this way, the electrical resistance of the filter may be varied to suit the actual situation. If the filter is used on e.g. a bus, the electrical resistance should be adapted to ensure a sufficient power to regenerate the filter and at the same time assure that the electrical system of the bus is not overloaded.

A filter for use in vehicles for long distance transport should be regenerated without having to park the vehicle in a garage for several hours. Furthermore, the filter should be regenerated while the vehicle is driving. If, however, the gas is guided through the filter during regeneration, a major part of the energy delivered to the filter to elevate the temperature thereof will be used to heat the gas emitted from the filter. Therefore, to assure efficient regeneration of the filter, two filters are usually used (dual filter design) whereby one filter filters the gas while the other filter is regenerated while the gas flow to this filter is stopped. This solution requires space and expenses for two filters. There is not much space for filters under e.g. busses, whereby it will be preferred to only have one filter. When using only one filter it is possible not to lead the gas through the filter during the regeneration thereof, and thereby not to filter the gas while regenerating the filter.

Thus, the present invention relates to a filter unit for filtering exhaust gas from diesel engines, comprising a casing and a filter body arranged in the casing, the filter body being composed of a plurality of filter segments extending in the axial direction of the casing, the filter segments being of a porous electrically conductive and heat-resistant material, the filter segments being arranged adjacent to each other, but being electrically

insulated from each at other at adjacent axially extending inter-faces.

By dividing the filter body, the necessary dimensions of which are dictated by the volume of exhaust gas it is to purify between regenerations, into a number of segments of smaller cross-sectional area, it becomes possible on the one hand to obtain the necessary purification capacity of the exhaust gas, and on the other hand to establish conditions with respect to electrical resistance or impedance of the filter segments which make regeneration realistic with available electrical power sources.

In most embodiments of the filter unit, each segment will be supplied with an electrode of an electrically conductive material substantially at each end of the segment in axial direction. Thereby, it becomes possible to arrange suitable electrical connections when regenerating the filter unit, these connections being either serial, or parallel where applicable, or a combination thereof, such as will be explained in greater detail in example 2. It also becomes possible to arrange the connections so as to simply regenerate one segment at a time, which is of importance in connection with filters for large diesel engines.

The resistance of each individual segment, measured from one electrode to the other, will normally be in the range from 10 milliOhms to 100 Ohms, preferably from 50 milliOhms to 50 Ohms, and more preferably in the range from 100 milliOhms to 25 Ohms.

In practical embodiments for smaller diesel vehicles, such as trucks, fork lifts, excavators or cars, the segments of the filter body will often be electrically coupled in series by means of the electrodes.

In one interesting embodiment according to the invention, the electrodes are connected to an electrical circuit

permitting an electrical connection of 2 or more segments variable between serial and parallel and, where applicable, combinations thereof. This embodiment makes it possible to vary the electrical resistance or impedance of the system during the regeneration, thereby utilizing the fact that the material, e.g. SiC, will change its resistivity or specific impedance during the heating, such as illustrated in example 1: The resistance of SiC will decrease with increasing temperature, for which reason the regeneration will be performed, in this embodiment with an initial electrical coupling involving parallel connection or a combination of parallel and serial connection, with subsequent change to a higher degree of serial connection or a total serial connection when the temperature increases.

The invention also relates to a filter body for use in a filter unit as discussed above, the filter body being composed of a plurality of filter segments extending in axial direction, the filter segments being of a porous electrically conductive and heat-resistant material, the filter segments being arranged adjacent to each other, but being electrically insulated from each at other at adjacent axially extending interfaces.

Because the most practical cross-section of a filter unit or filter body of the invention is a circular or substantially circular cross-section, it is preferred that the cross section of each segment is shaped substantially as a circle sector, the segments together cross-sectionally substantially constituting a circle.

The electrical insulation is provided by means of a layer of an electrically insulating heat-resistant inorganic material. The preferred electrically insulating heat-resistant material is a material containing a heat-expanding component which, when heated, expands, e.g. to an extent of 30-100%. This will ensure that during the first heating of the filter body, the component will expand and tightly fix

the filter segment of the filter body (which normally is encapsulated in a steel tubing).

As mentioned above, the porous electrically conductive heat-resistant material is preferably porous SiC.

SiC has primarily been used for heating elements, abrasives and fireproof construction materials due to its hardness, mechanical strength and temperature resistance.

SiC has a number of advantages over many other materials used in particle filters, such as metals and ceramics which have a very low thermal and electrical conductivity. SiC combines a high decomposition temperature (approx. 2500°C) with a, for non-metals, high electrical and thermal conductivity and a high corrosion resistance, even at high temperatures. SiC has a high mechanical strength, e.g. 7 times the strength of Alumina at 1000°C.

SiC is substantially more corrosion resistant than metals at high temperatures due to the formation of an oxidation resistant silica layer. At temperatures up to 800°C, the life time of a filter body will not to any substantial extent depend on corrosion. At higher temperatures, however, gasses with large amounts of alkali/chlorine/sulfur will corrode the protecting SiO_2-layer on the filter bodies, and the oxidation of SiC may be accelerated, but in the use of the filter unit according to the present invention, it will be possible to avoid such severe conditions.

The life time of a sintered SiC filter body depends on the operation temperature and the type of SiC used for the filter. Hexagonal alfa-SiC is stable at very high temperatures, whereas cubic beta-SiC is stable at temperatures up to 1700°C. At a temperature of 1600°C, the life time of a filter body is in the order of 1-3000 hours, whereas the life time probably is in the order of 20-30.000 hours during operation temperatures about 600°C.

The mean pore size of the porous SiC filter segments will normally be in the range of 1 to 150 μm, in particular 10-100 μm. The preferred sub-ranges within this range will depend on the particular separation to be performed, in particular on the size of the particles. Thus, for removal of soot particles from diesel exhaust gas, the pore size of the material will normally preferably be in the range of 15-80 μm, such as 20-50 μm. The higher the mean pore size, the lower the pressure drop over the segment will be.

The porosity of the particle-based conductive ceramic material significantly influences the strength of the material. Thus the porosity selected will depend on the required physical strength properties, the selected pore size of the filter body and the particles to be filtered, and will normally be in the range of 30-90%, typically in the range of 40-75%.

The thermal conductivity of the particle-based conductive ceramic material will normally be at least 15 W/mK and typically in the range of 15-90 W/mK, such as 20-40 W/mK. A high thermal conductivity will result in a high thermal shock resistance.

The electrical conductivity of the particle-based conductive ceramic material for use in filter body segments is preferably as high as possible, but physical limitations on the electrical conductivity of the ceramic material will set a maximum limit for the conductivity obtainable in the material. The conductivity should be is at least 0.001 S/cm at 20°C, preferably at least 0.01 S/cm at 20°C and more preferably at least 0.1 S/cm at 20°C. With suitable SiC-based materials, such as discussed in the following, conductivities of at least 1 S/cm at 20°C or even at least 10 S/cm at 20°C may be obtained.

This electrical resistivity of the filter bodies depend on, and may be regulated by, a number of factors such as:

- the quality and the type of SiC used,
- addition of other materials, silica, aluminum, beryllium, boron, or nitrogen,
- adjustment of the gas during sintering, adding metal halides to the filter body.

The particulate SiC will normally have a weight average mean particle size in the range of 10-250 μm, such as in the range of 20-150 μm, preferably in the range of 30-100 μm. The selected particle size and particle size distribution will normally be dictated by realistic available commercial grades and the pore sizes and other properties aimed at in the final material. Seven commercial grades of SiC are presently preferred starting products for producing the porous material.

One grade is particulate SiC of mesh 120, substantially corresponding to a particle size range of 88-125 μm.

Another grade is particulate SiC of mesh 150, substantially corresponding to a particle size range of 88-125 μm.

A third preferred grade is particulate SiC of mesh 180, substantially corresponding to a particle size range of 77-105 μm.

A fourth preferred grade is particulate SiC of mesh 220, substantially corresponding to a particle size range of 44-74 μm.

A fifth preferred grade is particulate SiC of mesh 280, substantially corresponding to a particle size range of 50-55 μm.

A sixth preferred grade is particulate SiC of mesh 320, substantially corresponding to a particle size range of 44-47 μm.

A seventh preferred grade is particulate SiC of mesh 360, substantially corresponding to a particle size range of 34-42 μm.

All of the above-mentioned seven grades of SiC have been found to be easy to use in the manufacture of the filter bodies and to perform excellently in preliminary tests.

The preferred SiC-based materials are materials in which the SiC particles have been bonded together in a sintering process. The sintering process is described in greater detail below and in the examples which follow.

In addition to a large amount of particulate SiC having a particle size in the ranges described above, the material to form the basis of the preferred SiC-based materials typically comprises, a smaller amount (up to 10 %wt) of a fine-grained (typically in the order of 0.3-2 μm) sintering additive such as SiC and/or SiO_2 and/or carbon black, a binder, such as cellulose ether, water and an alcohol such as ethanol.

A suitable mixture of the above ingredients, e.g. as described in example 1, will give a paste having a plasticity suitable for plastic shaping by extrusion, roller and jigger casting, etc.

The shaped body of paste, typically called a green body, is then dried in a controlled atmosphere for up to e.g. 200 hours. The dried green body is placed in a high temperature oven where the temperature is elevated to temperatures in the order of 300-500°C whereby the binder is burned away giving the SiC-body a rigid, open structure. Due to the smaller radii of curvature the fine-grained sintering

additive, these small particles will evaporate when further elevating the temperature to in the order of above 2200°C up to about 2600°C. When evaporating, this material will condense at the grain contacts of the larger SiC particles and hence enhance the physical strength and the electrical and thermal conductivity of the sintered material.

The mixed paste has a plasticity which permits a wide range of shaping methods again permitting a wide range of shapes of the porous filter segment.

A preferred method for shaping the paste is extrusion of the paste in an extruder known per se. This provides a cheap and simple shaping of a wide range of shapes of the filter segments. The limiting factor as to the dimensions and structures of the filter bodies is set by the tools forming the paste. The structure of the filter body is defined by the head of the extruder, and the length of the filter body is limited by the amount of paste that can be extruded from the extruder, and, of course, the capacity of the high temperature oven.

Filter bodies having cross sections defining a circle sector may be manufactured having radii as large as in the order of 250 mm and of a length up to 1000 mm. Also other hollow structures, having internal structures e.g. for strengthening purposes, may easily be manufactured by extrusion. This ensures that the thickness of the filtering surface of the filter body is not dictated by demands for rigidity or strength of the filter body. Using internal structures, the thickness of the filtering surface of the filter body may be selected only on the background of the desired filtering characteristics thereof.

Using the filter unit according to the invention, it is possible to regenerate one segment of the filter at the same time as an other part filters the gas, and thereby

obtain the advantages of the dual filter design and still only use the space used for one filter body.

As mentioned above, due to the characteristic of the electrical resistance of a SiC filter element as a function of temperature (see example 1), the power used to heat a filter element will decrease as the temperature rises. Using the filter unit according to the invention, it will be possible at all times to adapt the electrical resistance of the filter to optimize the power used in the filter for heating. This permits a shorter regeneration time for the filter.

$P = \frac{U^2}{R}$?

The invention will now be described in greater detail with reference to the drawings, wherein

Fig. 1 is a side view of a filter unit according to the invention,
Fig. 2 shows a cross section of the filter unit according to Fig. 1,
Fig. 3 is a side view of a filter segment as used in a filter unit as seen in Figs. 1 and 2,
Fig. 4 is a side view of a filter body as seen in Fig. 1, and
Fig. 5 shows a filter unit according to the invention comprising valve means for distribution the exhaust gas.

Fig. 1 is a side view of a filter unit 1 according to the invention, wherein a number of filter segments 2, 3, 4 and 5 are serially connected to increase the total electrical resistance of the connected filter segments 2, 3, 4 and 5 (See also Fig. 2). Two of the filter segments 2, 3, 4 and 5 are connected to electrical connectors 6 and 7 for connection to a power supply. Electrical connections 8, 9, 10 are formed between filter segments 2 and 3, 3 and 4 and 4 and 5, respectively, and electrical connections 18 and 19 are formed between filter segments 2 and 5 and the electrical connectors 6 and 7, respectively. These electrical connec-

tions may be of any suitable material, such as strips of copper soldered to the filter segments (see Fig. 3).

An electrically and thermally insulating layer 12 is placed in the space between the filter segments 2, 3, 4 and 5 and an inner casing 11, in which the filter segments 2, 3, 4 and 5, the electrical connections 8, 9, 10, 18 and 19, the insulating layer 12 and the sleeves 17 are positioned, and between the individual filter segments 2, 3, 4 and 5. The assembly of the filter elements 2, 3, 4 and 5 and the electrical connections 6 and 7 is hereafter denoted a filter body.

The insulating layer 12 may be made from a ceramic material and is preferably also a heat expandable material which will ensure that all gas is filtered by the filter body and that the filter body is kept in place at all times. This insulating layer 12 may be constituted by a mat of "Interam" manufactured by 3M. As the gas flow in the filter unit 1 may erode the parts of the insulating layer 12 exposed to the gas, erosion protecting sleeves 17 are preferably formed to prevent or reduce the gas flow eroding the insulating layer 12. These sleeves 17 cover all of the insulating layer 12 and are preferably also heat expandable to ensure stable positioning in the filter body 1. These sleeves 17 should be an electrical and thermal insulator, such as a ceramic material. These sleeves 17 may be constituted by a strip of Interam placed in a hose of Nextel, also manufactured by 3M; Nextel is a woven hose of ceramic material, based on alumina-bor-silicate fibres being flexible temperature resistant fibres.

The inner casing 11 is preferably positioned in an outer casing 13, and an additional layer of heat insulating material 14 is positioned between these layers to reduce the heat loss to the surroundings. This insulating layer 14 may be made of e.g. a Al-Si-oxide fibre material. The inner casing 11 and outer casing 13 may be made of 1.5 mm stain-

less steel. The filter unit 1 additionally comprises an entrance funnel 15 and an exit funnel 16 for guiding the gas through the filter body.

Fig. 2 shows the cross section of the middle of the filter unit 1 in Fig. 1 When, thus, comparing figs. 1 and 2, it is seen that during regeneration of the filter unit 1, the electrical current may flow through the electrical conductor 6, the electrical connection 18, the filter segment 2, the electrical connection 8, the filter segment 3, the electrical connection 9, the filter segment 4, the electrical connection 10, the filter segment 5, the electrical connection 19 and the electrical connector 7.

By decreasing the cross-sectional area of the filter segments 2, 3, 4 and 5 by 1/4 of that of the filter not splitted into the individual filter segments 2, 3, 4 and 5, and in the same time increasing the length by a factor of 4, the total resistance of the filter unit 1 is increased by a factor in the order of 16. This increase in the resistance of the filter unit 1 does not affect the filtering capability of the filter unit 1 as the filter segments 2, 3, 4 and 5 together have the same filtering ability as the filter would have if it was not splitted up into the individual filter segments 2, 3, 4 and 5.

Fig. 3 is a side view of a filter segment 2 on which electrical connections 18 and 8 are soldered. The filter segment 2 is preferably metal sprayed with e.g. Al to enable electrical contact to the filter segment by soldering. It is possible to solder electrical connections 18 and 8 directly on to flame sprayed areas 22 of the filter segment 2.

Fig. 4 is a side view of a filter body as seen in Fig. 1 wherein four filter segments 2, 3, 4 and 5 are positioned and where the insulating layer 12 and the sleeves 17 are comprised. When the individual constituents are positioned

in the inner casing, the electrical connections 8, 9, and 10 are formed. The filter segments 2 are preferably of the type shown in Fig. 3 where electrical connections 18 and 8 are e.g. soldered to each end of the filter segment 2. As all filter segments 2 have electrical connections electrically connecting the ends of the filter segments 2, these electrical connections should be interconnected to form the electrical interconnection of the filter segments 2 in the filter body. This interconnection of the electrical connections may be performed in ways known per se, such as soldering or welding. The connection of the electrical connections 18 and 19 to the electrical connectors 6 and 7 may also be performed by e.g. welding or soldering, or by fastening by e.g. screws.

Fig. 5 shows a filter unit 1 according to the invention formed by four filter segments 2, 3, 4 and 5 as seen in Fig. 1. In this filter unit 1, the electrical connection 9 is removed so that the filter segments 2, 3, 4 and 5 are divided into two groups each of two segments: (2, 3) and (4, 5). Valves 22 guide the exhaust gas to one of the groups of filter segments, and a dividing wall 23 assures that gas guided to one group of filter segments is not able to reach the other group of filter segments. When supplying this filter unit 1 with four electrical connectors (of which only two are shown: 6 and 7) and connecting the electrical connections constituting the electrical connection 9 in Fig. 1 to the two electrical connectors not shown, these two groups of filter segments (2, 3) and (4, 5) may be regenerated individually.

In this way, a single filter body may be used in the same way as the dual filter setups are usually used: regenerating one filter while filtering the gas through the other filter. By using a filter according to the invention, the dual filter setup may be formed in one container where one group of filter segments 2 may be regenerated while the gas is filtered through the other group of filter segments 2.

Normally, the filters in a dual filter setups are placed in separate containers to reduce the heat loss due to the gas flowing through the filter during regeneration; the filtered gas would remove part of the heat generated in the filter. As gas is not able to flow from one filter segment 2 to another, the filter segments 2 may be regenerated individually without excessive loss of heat to the flowing gas.

EXAMPLE I

Manufacturing and properties of the SiC-bodies.

The recipe for the ceramic substance may be varied for different purposes for example in order to improve extrusion results or sintering results. A typical recipe may be:

	wt%	vol%
Cellulose ether	4-6	7-10
Ethanol	0-12	0-28
Water	8-25	28-45
Coarse SiC (88-125 μm diameter)	69-72	42-45
Fine SiC (Submicron, FCP 10-S)	4-13	2-8

The ingredients are weighed in separate containers. Firstly, the dry ingredients (coarse and fine SiC, cellulose ether) are mixed. Then alcohol is added and finally the water is added. After additional mixing the substance is ready for extrusion.

The extrusion process is preferably performed using a standard single auger extruder.

The mixed substance is fed into the feeding auger of the extruder where the substance is conditioned. From here it is pressed through a noodle-die, transforming the substance into "noodles" which are chopped up by a rotating knife. The substance now falls into the vacuum chamber of the

extruder. From the vacuum chamber the substance is now transported by the main auger, which compresses and homogenizes the substance. The substance is pressed through the extrusion head at a pressure in the range of 15-80 bar and is received on a electronically controlled table or on a table with an air cushion. The bodies are cut in suitable lengths by a grinder, and are placed in a container to be used when drying the bodies.

The extrusion pressure is typically in the range of 15-80 bar for bodies with a cross sectional area of 60 cm^2.

The extruded honeycomb bodies are dried in air and the channels are plugged e.g. in a checkerboard manner as described in EP 0 089 756 (Corning), whereafter the bodies are placed in an oven and heated.

After pyrolysis of the binder the bodies are sintered in an electrical heated furnace in an argon atmosphere for 15 to 120 minutes at temperatures above 2200°C.

The sintered bodies are thermally sprayed with Al in order to produce electrical contacts.

The porosity of the bodies is in the range of 40-60 % with a mean pore size in the order of 50 μm.

The resistance of the bodies depends on the purity of the raw SiC-grains, the amount of additives, the sintering temperature/time, the grain size and on the porosity of the sintered elements.

Table 1 shows the resistance of different SiC-bodies having a porosity of 50%, a length of 250 mm and a cross section of a quarter of a circle with a radius of 90 mm (figure 2). The wall thickness is 1 mm and the cell width is 2,5 mm.

TABLE 1

Material	SIKA III	SIKA III	SIKA I
Sintering-temperature	2300°C	2400°C	2400°C
Resistance at 20°C	9 Ω	8 Ω	1 Ω
Resistance at 200°C	4 Ω	4 Ω	0.4 Ω
Resistance at 400°C	3 Ω	3 Ω	0.35 Ω
Resistance at 600°C	2 Ω	1.6 Ω	0.3 Ω

The designation SIKA I and III corresponds to the delivery brochure from the manufacturer of the SiC, Arendal Smelte-verk. SIKA I is 99,7 % pure SiC and SIKA III is 99,2 % pure SiC.

As the table shows, SiC has a negative temperature-resistivity dependence with a decreasing resistance when the temperature is increased.

EXAMPLE 2
240 VAC application

The most commonly used voltage from ordinary main supplies is 240 V AC where there typically is an upper limit for the available current (10 A). This may be used as a basis for the stationary electrical regeneration of the particulate loaded trap.

By modifying the raw materials (i.e. quality and additives) and the particle size of the SiC material to be sintered or by modifying the electrical setup of the filter segments and the power supply, it is possible to compensate for the negative temperature-resistivity behaviour of SiC (See example 1) in order to obtain appropriate properties for the self heated electrical regeneration of the filter segments.

A typical filter according to the invention for a 2-3 litre diesel engine on e.g. a fork lift consists of 4 SiC segments manufactured as described in example 1 formed to be honeycomb segments (wall thickness of 1 mm and channel width of 2,5 mm) having a length of 500 mm and a cross section describing a quarter of a circle with a radius of 60 mm. The raw material used is 99.2 % SiC (the SIKA III grade from Arendal Smelteverk) without sintering additives.

The resistance of one of these segments is 15 Ω at 20 °C and 5 Ω at 600 °C.

The segments are connected in series of two, which again are coupled parallel to each other. This gives a total impedance of 15 Ω at 20°C. This electrical coupling principle is required to compensate for the relatively high resistance of a cold segment compared to the resistance of a hot segment.

At 400°C the electrical coupling is altered, using e.g. power relays or solid state relays, so that the four bodies are now connected in series, which results in an overall resistance of 30 Ω at 400°C and 20 Ω at 600°C.

The power consumption during the electrical regeneration is controlled by using a thyristor to limit the current to a maximum of e.g. 10 A.

Using this change in the overall electrical resistance of the filter, the heating of the filter segments may be made more efficient as if the resistance was kept constant. As the resistance is altered, the change in the resistance of the sintered SiC sue to the change in temperature is compensated for.

EXAMPLE 3
24 V DC application

The standard electrical system on a common heavy-duty diesel vehicle is 24 V DC. Due to the power supply being a generator and/or an accumulator there is an upper limit of current available: 50 to 100 A depending on the type of generator and/or accumulator. Using this type of regeneration, a filter body in which the filter segments are divided into groups, preferably two groups, is used so that one group of filter segments may filter the gas while the other group of filter segments is regenerated (See Fig. 3).

The filter segments filtering the gas are preheated during operation to in the order of 200°C by the hot exhaust gases from the engine. When the temperature of the filter is e.g. 200°C and the pressure drop over the filter reaches e.g. 200 mbar, a valve system is activated so that the valves (20 on Fig. 3) change from open to closed position and vice versa. In other words the active filtration process is moved from one group of filter segments to the other, so that the polluted filter segments may be regenerated.

For a typical heavy duty truck or bus having a 10 litre diesel engine, a total filter volume of 4*9 litres = 36 litres is appropriate, when one half of the filter unit, consisting of 2 segments with a total volume of 18 litres, is used at a time.

In the passive group of filter segments, corresponding to the closed valve, one of the filter segments is separately

connected to the 24 V DC on the vehicle's electrical system and the temperature in this segment is raised from 200°C to 600°C by transmitting a current through the filter segment. During this heating process, the filter segment is regenerated and the collected particulates are incinerated by oxidation.

Each segment is heated for about 20 minutes. As it will typically take in the order of 3-4 hours before a filter is to be regenerated, there is more than sufficient time for such 2 regenerations in each group of filter segments in the filter body.

A filter unit thus preferably consists of 4 filter elements. These segments are manufactured from SIKA I (99,7% pure SiC) material as described in example 1 (length: 600 mm and a cross section as a quarter of a circle with a radius of 140 mm) and coupled separately to 24 V DC on the vehicle. The electrical resistance of one filter segment is in the order of 1 Ω at 20°C, 0.6 Ω at 200°C and at 600°C the electrical resistance is in the order of 0.4 Ω for one segment.

When only one of the two polluted segments (and passive as to the filtration) is electrically heated and regenerated at a time, the maximum power load on the electrical system of the vehicle is reduced to 60 A corresponding to a little less than 1500 Watts.

This is a low value comparing to a filter consisting of only one segment where the power consumption is more than 6000 W which would require an extensive expansion of the existing electrical system on the vehicle. If the filter was of the dual filter setup, two filters will be used, whereby the power consumption will be 3000 W, which is still more than the existing electrical system of the vehicle can deliver.

Claims

1. A filter unit for filtering exhaust gas from diesel engines, comprising a casing and a filter body arranged in the casing, the filter body being composed of a plurality of filter segments extending in the axial direction of the casing, the filter segments being of a porous electrically conductive and heat-resistant material, the filter segments being arranged adjacent to each other, but being electrically insulated from each other at adjacent axially extending interfaces.

2. A filter unit according to claim 1, wherein each segment is supplied with an electrode of an electrically conductive material substantially at each end of the segment in axial direction.

3. A filter unit according to claim 2, wherein the resistance of each individual segment, measured from one electrode to the other, is in the range from 10 milliOhms to 100 Ohms.

4. A filter unit according to claim 2, wherein the resistance of each individual segment, measured from one electrode to the other in axial direction, is in the range from 100 milliOhms to 25 Ohms.

5. A filter unit according to any of the preceding claims, wherein the segments are electrically coupled in series by means of the electrodes.

6. A filter unit according to any of claims 1-4, wherein the electrodes are connected to an electrical circuit permitting an electrical connection of 2 or more segments variable between serial and parallel and, where applicable, combinations thereof.

7. A filter body for use in a filter unit according to any of the preceding claims, the filter body being composed of a plurality of filter segments extending in axial direction, the filter segments being of a porous electrically conductive and heat-resistant material, the filter segments being arranged adjacent to each other, but being electrically insulated from each at other at adjacent axially extending interfaces.

8. A filter unit according to any of claims 1-6 or a filter body according to claim 7, wherein the porous electrically conductive heat-resistant material is porous SiC.

9. A filter unit according to any of claims 1-6 or a filter body according to claim 7, wherein the cross section of each segment is shaped substantially as a circle sector, the segments together cross-sectionally substantially constituting a circle.

10. A filter unit or filter body according to any of the preceding claims, wherein the electrical insulation is provided by means of a layer of an electrically insulating heat-resistant inorganic material.

11. A filter unit according to claim 10, wherein the electrically insulating heat-resistant material is a material containing a heat-expanding component.

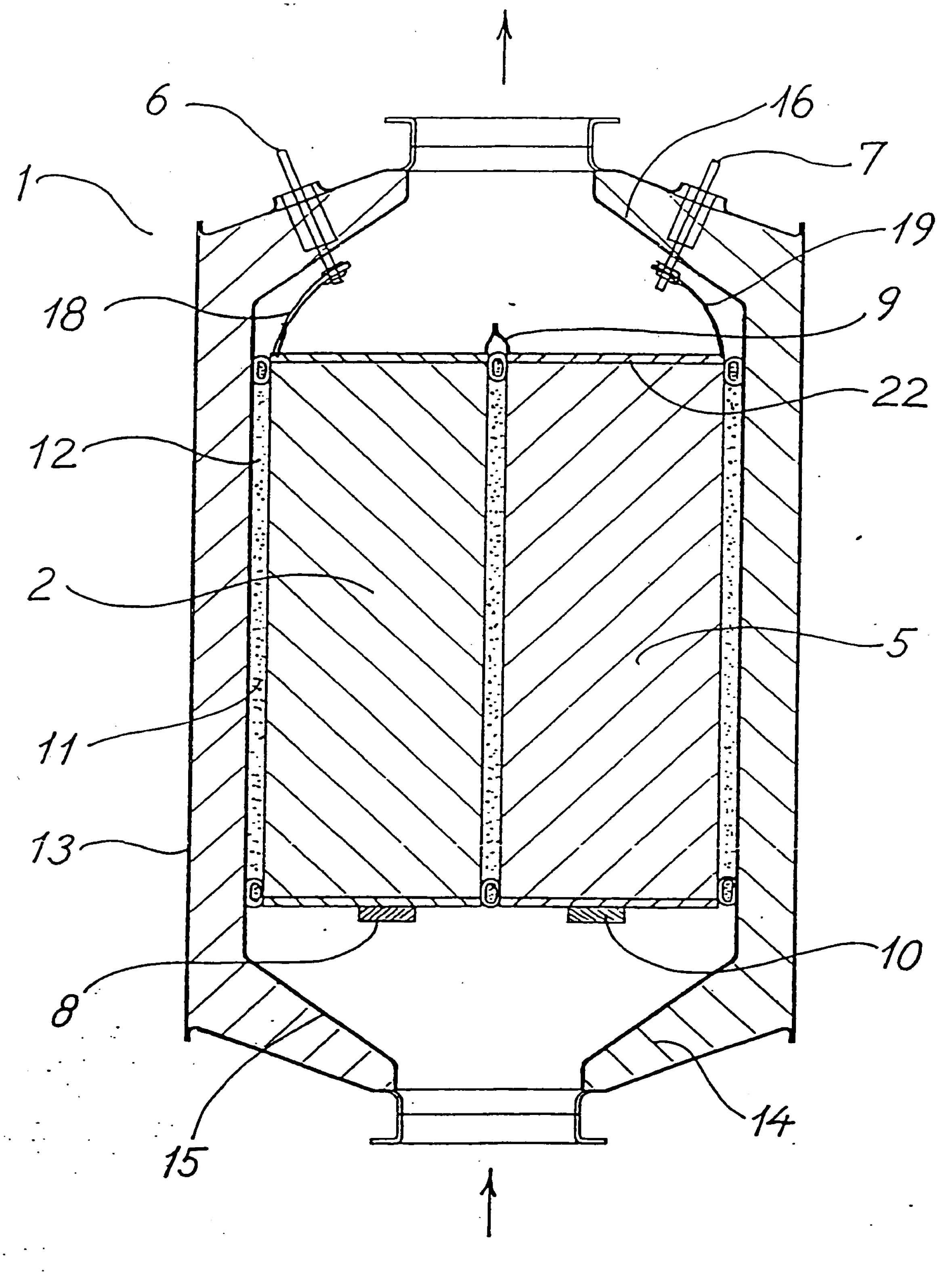

Fig. 1

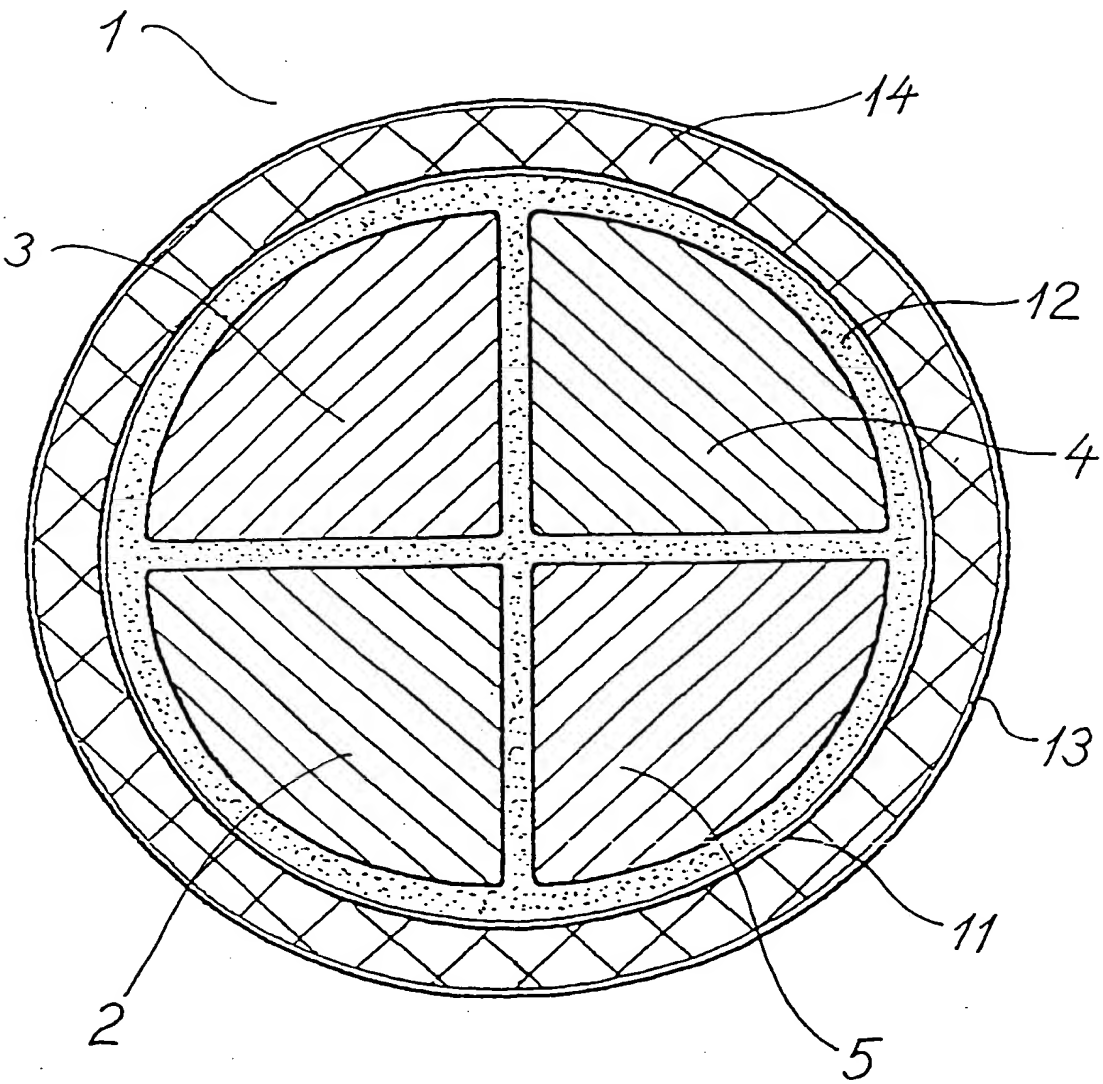

Fig. 2

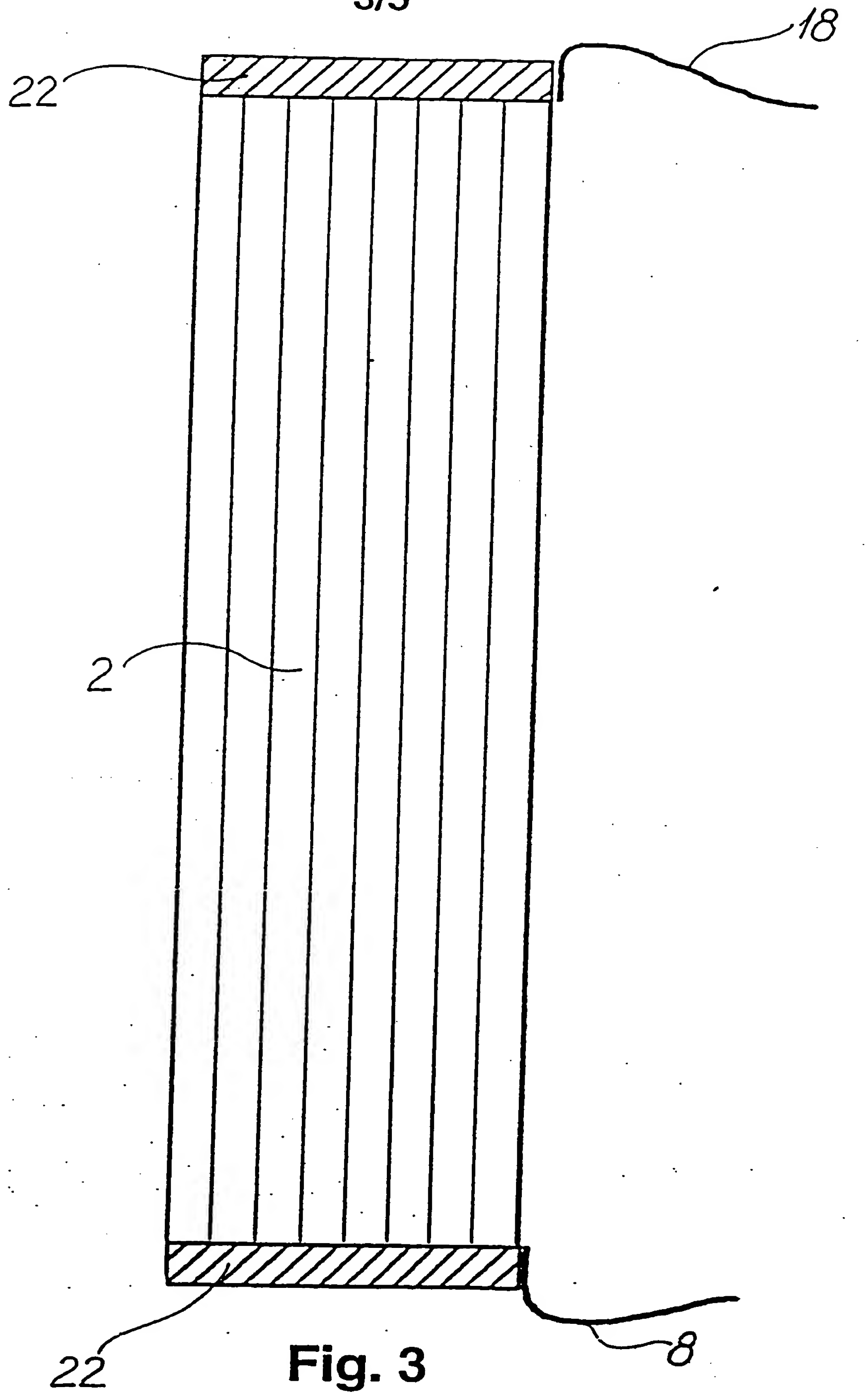

Fig. 3

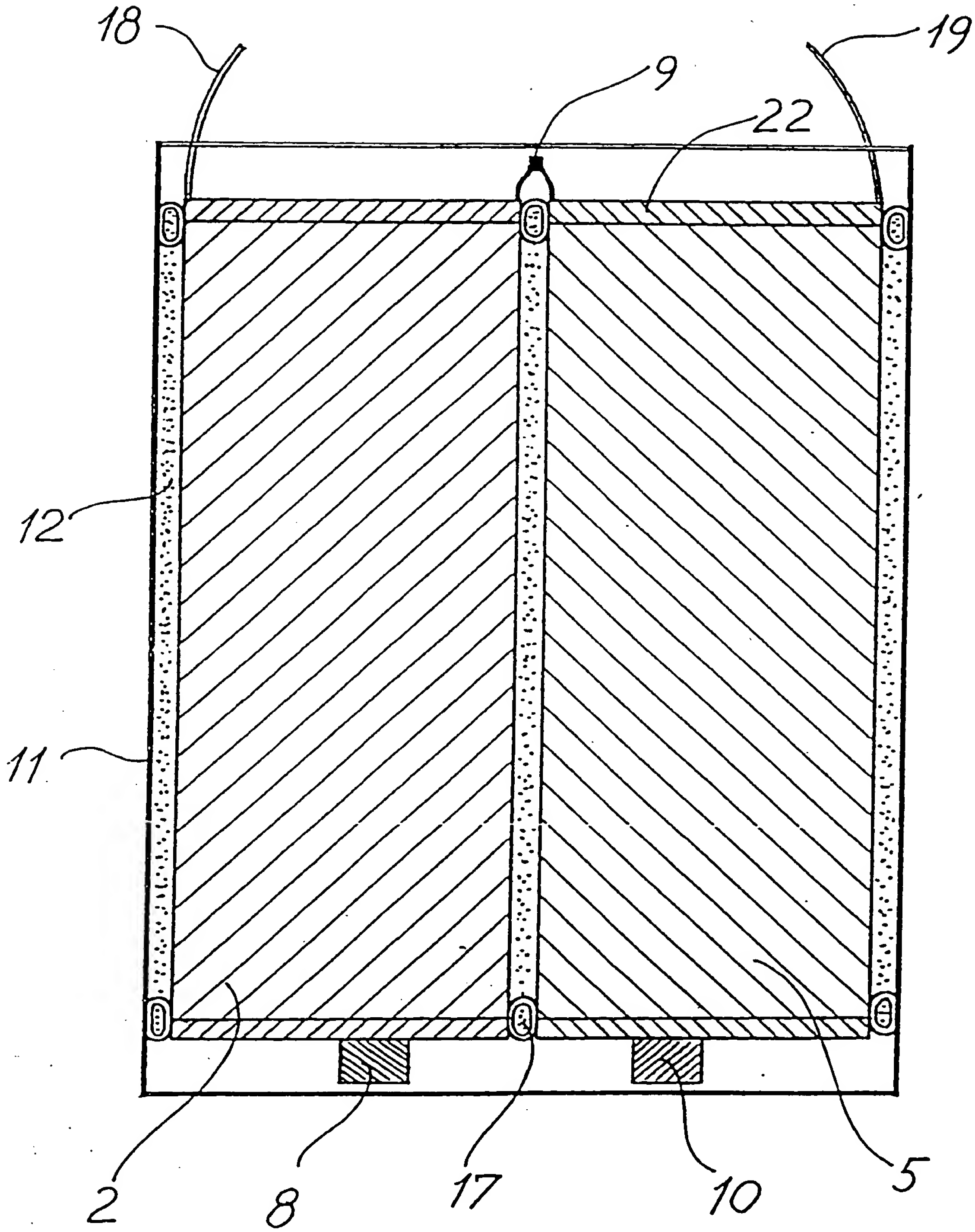

Fig. 4

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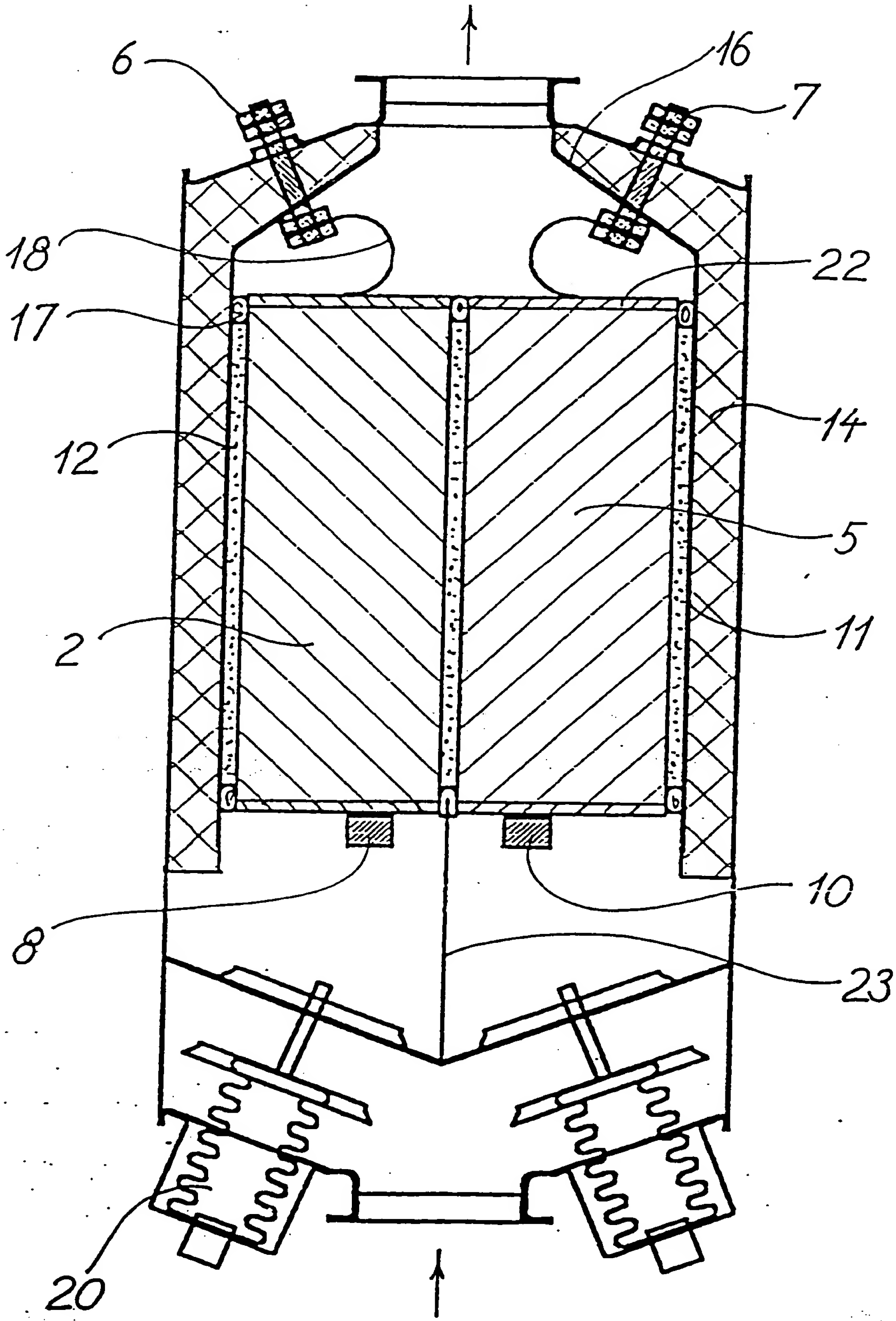

Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/DK 92/00393

A. CLASSIFICATION OF SUBJECT MATTER

IPC5: F01N 3/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: F01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP, A1, 0336883 (STOBBE, PER), 11 October 1989 (11.10.89), claims 1-6, abstract --	1-11
A	EP, A2, 0393729 (IVECO FIAT S.P.A.), 24 October 1990 (24.10.90), figure 1, claim 1, abstract --	1-11
A	EP, A1, 0270990 (IVECO FIAT S.P.A.), 15 June 1988 (15.06.88), claim 1, abstract -- --------	1-11

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
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- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing f the international search report
25 March 1993	30 -03- 1993
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INTERNATIONAL SEARCH REPORT
Information on patent family members

26/02/93

International application No.
PCT/DK 92/00393

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A1- 0336883	11/10/89	AU-A- 3449989	03/11/89
		WO-A- 8909648	19/10/89
EP-A2- 0393729	24/10/90	SE-T3- 0393729	
		DE-A- 3772013	12/09/91
		DE-A- 3782176	12/11/92
		EP-A,B- 0270990	15/06/88
		SE-T3- 0270990	
EP-A1- 0270990	15/06/88	SE-T3- 0270990	
		DE-A- 3772013	12/09/91
		DE-A- 3782176	12/11/92
		EP-A,B- 0393729	24/10/90
		SE-T3- 0393729	